PATENT APPLICATION

ROTARY TARGET

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the filing of U.S. Provisional Patent Application Serial No. 60/393,547, entitled "Rotary Targets for Deposition of Metal Films," filed on July 2, 2003, and the specification thereof is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

The present invention relates to rotary targets preferably used for depositing metal films on selected substrates.

Description of Related Art:

Note that the following discussion refers to a number of publications by author(s) and year of publication, and that due to recent publication dates certain publications are not to be considered as prior art vis-à-vis the present invention. Discussion of such publications herein is given for more complete background and is not to be construed as an admission that such publications are prior art for patentability determination purposes.

U.S. Patent No. 4,151,064, entitled "Apparatus for Sputtering Cylinders," to Kuehnle, issued April 24, 1979, discloses a device for sputtering a coating onto a thin-walled metal sleeve. The device is capable of being configured to form a cylinder or a rigid drum-like member. This device is not a segmented rotary target.

U.S. Patent No. 4,356,073, entitled "Magnetron Cathode Sputtering Apparatus," to McKelvey, issued October 26, 1982, discloses a rotatable magnetron cathode sputtering device for operation within an evacuable chamber. The device is for coating substrates that are also contained within said chamber. The cathode is an elongated cylinder, and the sputtered materials are applied on the surface of the cylinder. This device is not segmented, and does not have an adjustable length.

U.S. Patent No. 4,443,318, entitled "Cathodic Sputtering Apparatus," to McKelvey, issued April 17, 1984, discloses the use of segmented rectangular targets that are attached longitudinally to a tubular cylinder. The cylinder can be rotated to a specific position relative to the substrate and a different metal deposited. This device does not use cylindrical segments that fit in a sleeve manner.

U.S. Patent No. 4,445,997, entitled "Rotatable Sputtering Apparatus," to McKelvey, issued May 1, 1984, discloses an elongated, tubular magnetron cathode for sputter-coating which is contoured longitudinally to provide a non-cylindrical sputtering surface. This device is not segmented, and does not have an adjustable length.

U.S. Patent No. 5,073,245, entitled "Slotted Cylindrical Hollow Cathode/Magnetron Sputtering Device," to Hedgcoth, issued December 17, 1991, discloses a hollow, longitudinal cathode with an interior coated wall. This device is designed to deposit film on a planar substrate, has no moving parts and allows for even coating of the cathode. This device is not a segmented rotary target.

U.S. Patent No. 5,437,778, entitled "Slotted Cylindrical Hollow Cathode/Magnetron Sputtering Device," to Hedgcoth, issued August 1, 1995, and U.S. Patent No. 5,529,674, entitled "Slotted Cylindrical Hollow Cathode/Magnetron Sputtering Device," to Hedgcoth, issued June 25, 1995, disclose a cylindrical target in which the material to be sputtered is positioned in the interior walls of the cylinder. During the sputtering process, a filament or sheet to be coated continuously passes through the interior of the target. These devices do not use segmented cylindrical targets.

U.S. Patent No. 5,683,558, entitled "Anode Structure for Magnetron Sputtering Systems," to Sieck et al., issued November 4, 1997, discloses an elongated anode structure having multiple points to attract electrons. In one embodiment of the device, is a magnetron system having a cylindrical cathode and a pair of elongated anodes positioned parallel to and equidistant from the cathode.

Physical vapor deposition, also known as sputtering, is a process whereby ions of an inert gas, such as argon, are electrically accelerated in a high vacuum towards a target of a metal (e.g. an ultra-pure metal) or an alloy thereof. The ions physically chip off, or sputter, the target material, which is then deposited as a film on the surface of the substrate. Physical sputtering is the process often involved in the coating of a semiconductor wafer or other substrate mounted within a processing chamber. An inert gas is introduced into the processing chamber and an electric field is applied to ionize the inert gas. The positive ions of the inert gas bombard the target material and dislodge atoms from the target which are subsequently deposited onto the wafer or other substrate in the form of a thin metal film.

The target is held within the deposition chamber by a device called a sputter coating source. The sputter coating source embodies electrical means for biasing the target material structure with a negative voltage, either DC for conductive targets, or RF for non-conductive targets, so the target will attract positive ions from the plasma of an inert gas. The sputter coating source also contains means for cooling the target structure and often magnetic means for containing and enhancing the plasma. One reason for manipulating the heat distribution and/or magnetic field about the target material is to control the uniform depletion of the target material. Otherwise a target tends to wear in one location, thereby causing more down time due to the increase in the replacement of the target within the processing chamber. This, as well as other handling factors, increases operating costs. An alternative or conjunctive solution to the uneven wearing of targets is the use of rotary targets. A rotary target generally comprises a cylinder of a specified metal of specific length and diameter.

Although segmented rotary targets are known in the art, all such targets are formed by joining each half of the segment. In other words, the segments possess the shape of an open clamshell. The two halves are placed about the backing tube and then welded or joined together. Unfortunately, the welding or joining process is the source of unwanted impurities and uneven coatings in such prior targets.

The present invention overcomes the present shortcomings of relatively large rotary targets by utilizing segmented rotary targets. Essentially, rather than forming or casting metal targets in one piece, the targets are formed or cast in segmented, i.e., relatively shorter lengths. The segments are then slipped on or otherwise attached to a backing tube or backing structure, one at a time, until the desired overall length is achieved. Thus, the invention overcomes many of the disadvantages associated with prior rotary targets. The segmented targets also ease the logistical problems associated with handling and shipping long heavy target cylinders.

BRIEF SUMMARY OF THE INVENTION

The present invention is a rotary target utilized in a physical deposition processing chamber. The rotary target comprises at least one segment rotary target made of metal, ceramic, refractory, alloy, oxide or other suitable material that may be placed on a backing tube to produce a rotary target sized specifically for an application. The rotary target segments may have joints and seams between the segments, and there may also be joints and seams between the rotary target segments and the backing

tube. The joints and seams may be, but are not limited to, a square cut, a tapered cut, an interference slip fit, a threaded fit, a compression or locking ring, a lock and key fit, and the like.

The rotary target preferably comprises at least two rotary target segments disposable around a backing tube and disposable in serial position to each other, and a joint between the segmented targets. The rotary target may comprise more than two rotary target segments. Likewise, the rotary target may be a single segment, attachable to the backing tube on site.

The rotary target segments may comprise a metal (e.g. pure metal), a refractory, ceramic, alloy, oxide, and the like. Such materials include, but are not limited to, gold, silver, copper, niobium, tantalum, platinum, palladium, rhodium, iridium, ruthenium, osmium, carbon, silicon, molybdenum, tungsten, vanadium, zirconium, chromium, beryllium, nickel, chrome, nickel-chrome, aluminum, zinc, tin, tin-zinc, zinc-aluminum, high intrinsic value materials and the like. The rotary target segments and joints preferably have substantially little or no impurities.

The rotary target may be any diameter. Preferably, the diameter of the rotary target is between approximately 3 centimeters and approximately 50 centimeters. The rotary target may be any length. Preferably, the length of the rotary target is between approximately 1 foot and approximately 4 meters.

The method and apparatus of disposing the rotary target segments onto the backing tube comprise alternately and in combination mechanical attachment or assembly and disassembly, on-site, included but not limited to the following: a square cut, a tapered cut, an interference slip fit, a threaded fit, a compression ring, a lock and key fit, and the like. The joints and seams of the rotary target preferably comprise smooth joints between the rotary target segments.

The preferred embodiment of the rotary target employs a locking or compression ring for placement of one or more rotary target segments onto the backing tube. The rotary target segment abuts against or slides under a compression ring on the backing tube to secure the rotary target segment. A compression ring assembly, comprising an inner and outer threaded clamshell type ring and hinge, is the preferred embodiment. The inner ring is disposed in a groove of the backing tube for stabilizing the ring assembly. The outer ring threads onto the inner ring, or abuts and goes under the rotary target segment.

In an alternative embodiment the backing tube has an end compression fitting. Preferably the compression fitting is on an end cap that is threaded onto the backing tube. The end cap is removed,

the rotary target segment slides onto the backing tube and the end cap is screwed back onto the backing tube.

Another embodiment is the method and apparatus of a lock and key cut between at least one of the rotary target segments and the backing tube or between rotary target segments. The lock and key cut comprises aligning a groove on the backing tube or a segment with a key portion of the rotary target segment.

Threading the rotary target segments onto the backing tube or to each other is another embodiment of the present invention. The backing tube may be threaded along its entire length, along most of its length, along only a portion of its length, or at specific areas of its length (e.g. at an end of each segment). The rotary target segments are then threaded onto the backing tube to create an appropriately sized rotary target.

Another embodiment of the present invention utilizes an interference slip fit method and apparatus. In this embodiment, the rotary target segments have an inner diameter which is slightly smaller and substantially equal to an outside diameter of the backing tube. The rotary target segments are heated or warmed and expanded, and placed or slipped onto the backing tube. The rotary target segments are then cooled to create a tight fit with the backing tube. In another embodiment, the backing tube is cooled and shrunk, and then the rotary target segments are disposed or slipped onto the backing tube. The backing tube is warmed or heated which creates a tight fit between the backing tube and the rotary target segments. In yet another embodiment, the rotary target segments are just slightly larger than the backing tube and are disposed onto the backing tube. Suitable materials which can expand and contract are useful in accordance with the interference slip fit method.

In alternative embodiments, a method and apparatus for disposing the rotary target segments onto the backing tube may cause spaces between the rotary target segments, or the rotary target segments and the backing tube. These spaces maybe filled in accordance with the present invention. These spaces may be backfilled using an adherent or adhesive material. Useful adherent materials preferably comprise a low vapor pressure metal including, but not limited to, indium, silver, and metal alloys. Useful adhesive materials preferably comprise thermally and/or electrically conductive materials.

After the target is spent, it can be removed or disassembled form the backing tube on-site. The backing tube can then be reused with a new rotary target segment assembled thereon.

A primary object of the present invention is to provide a segmented rotary target for depositing metal films on selected substrates. Another object of the present invention is to provide rotary target segments that can be disposed on-site, on a backing tube.

The main advantage of the present invention is that the end user does not have to ship back the backing tube and can reassemble the target on-site. Another advantage of the present invention is the ability to adjust the length of the target, achieve uniform target wear, introduce no impurities and resolve logistical issues present with large rotary targets.

Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate several embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating a preferred embodiment of the invention and are not to be construed as limiting the invention. In the drawings:

Fig. 1a and b are side views of a removable locking ring of the preferred embodiment of the present invention for rotary targets;

Fig. 2 is a side view of a preferred embodiment of Fig. 1;

Fig. 3 is an end view of an inner ring of the Fig. 1 embodiment;

Fig. 4 is a cross-sectional side view of a threaded portion of the inner ring of the Fig. 1 embodiment;

Fig. 5 is an end view of an inner ring hinge of the Fig. 1 embodiment;

Fig. 6 is an end view of the inner ring hinge of the Fig. 5 embodiment;

Fig. 7 is an end view of an outer ring of the Fig. 1 embodiment;

Fig. 8 is a cross-sectional view of the threaded portion of the outer ring of the Fig. 1 embodiment;

Fig. 9 is a side view of an outer ring hinge of the Fig. 1 embodiment;

Fig. 10 is a top view of an outer ring hinge of the Fig. 1 embodiment;

Fig. 11 is a side view of a rotary target with rotary target segments disposed serially on a backing tube;

Fig. 12 is a side view of a rotary target showing a lock and key fit of a rotary target segment disposed on a backing tube;

Fig. 13 a-c illustrate a perspective and end view of an interference slip fit of a rotary target segment disposed on a backing tube;

Fig. 14 is a side view of a rotary target showing a rotary target segment disposed on the backing tube by threading along the entirety of the length of the backing tube; and

Fig. 15 is a side view of a rotary target showing rotary target segments disposed on the backing tube by threading at specific areas of the backing tube.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a rotary target useful with a backing or arbor utilized in a physical deposition processing chamber.

In the prior art, the end user or customer usually has to purchase new backing tubes or ship back the old backing tubes to the manufacturer so that the rotary target can be assembled onto and bonded to the backing tube. The present invention offers a huge advantage in that the customer disassembles and removes the spent rotary target segments from the backing tube, needs only to purchase the new rotary target segments, keeps the backing tube, and then can do its own assembly on-site with the new rotary target segments. There are cost savings due to reusable backing tubes and lower shipping costs for just the rotary target segments. With rotary target segments, rather than single rotary targets, the shipping is also easier and less expensive. The assembly and disassembly can be done with simple tools, e.g. spanner wrenches, strap wrenches, etc. No chemical bonding, off-site or on-site, is required. The attachment is done by mechanical means, including but not limited to the various embodiments described herein, such as interference slip fit, compression or locking ring, lock and key, threading, and the like.

As shown in the drawings, rotary target **10** comprises cylinder **12** of a metal, ceramic, refractory, alloy, oxide, and the like. The target metals useful in accordance with the present invention include gold, silver, copper, niobium, tantalum, platinum, palladium, rhodium, iridium, ruthenium, and osmium, carbon, silicon, molybdenum, tungsten, vanadium, zirconium, chromium, beryllium, nickel, chrome, nickel-chrome, aluminum, zinc, tin, tin-zinc, zinc-aluminum, as well as any other metals and other

materials, including high intrinsic value materials. This listing is not meant to be comprehensive; other materials may also be used in the present invention.

The overall dimensions of composite target cylinder **12** of the present invention can be any size, but preferably as large as up to 50 centimeters in diameter and up to 4 meters in length and as small as several centimeters in diameter and one foot in length. The target cylinder comprises at least one or more rotary target segments **14, 14'** that are then fitted over backing tube **16** (see Fig. 12) of similar dimension. Joints **18** located between each individual segment may comprise a square cut, a tapered cut (as shown in Fig. 11), a lock and key cut or other joints, depending on the application. The joint should create a smooth transition. Likewise, a seam may also be used referred to as a "joint" in the claims. For example, if a rotary target is to be two meters in length, there are a number of ways to construct the target with that specific dimension from individual rotary target segments. The present invention thus allows that target to either comprise two, one meter segments; four, half meter segments; eight, quarter meter segments, and so on. The stated dimensions are used to describe the present invention, and are not meant to limit the dimensional size of the rotary target of the present invention in any way.

Close Fit and Locking or Compression Ring

In another embodiment (see Fig. 12, right end), rotary target segments **54** are slid onto the backing tube **56**. The segment **54** abuts against a step or rim on the backing tube **56**. After the last segment **54** is placed upon backing tube **56**, a compression fitting **58** is disposed on the opposite end of the backing tube **56**, thereby securing the target segments **54** upon the backing tube **56**. Seams or joints located between each individual segment should be smooth.

The rotary target segments **28** may also be held by compression or locking fitting **32** between each segment or at the end of backing tube. Compression fitting **32** comprises of inner ring **40** (Figs. 1-3) and outer ring **42** (Figs. 1a, 1b, 2 and 7). Inner ring is threaded **46** (Figs. 1a and 4), and outer ring **42** is cooperatively threaded **48** (Figs. 1a, 1b and 8). Inner ring **46** is preferably hinged **50** (Figs. 5 and 6) and outer ring **42** is hinged **52** (Figs. 9 and 10). Rings **40** and **42** connect in a clamshell fashion, and open opposite hinges **50** and **52**. They interconnect with threading **46** on inner ring **40** fitting into threading **48** on outer ring **42**. The compression fitting **32** is then disposed on the backing tube **30**. (See Fig. 1a and 1b). Fig. 1b shows the left end of the rotary target which is fixed. The right end of figure 1b shows the compression fitting.

The compression fitting may abut the rotary target segment or slide underneath the end of the rotary target segment. Both methods hold the rotary target segment in place on the backing tube.

Interference Slip Fit

As shown in Fig. 13 a-c (diameters exaggerated in drawings to illustrate the expansion), one embodiment of the present invention is to provide a rotary target segment **14,** with an inner diameter that is slightly smaller (See Fig. 13c), slightly larger or nearly identical (See Fig. 13b) to the outside diameter 6 of the backing tube. Each cylindrical, rotary target segment **14** is then heated prior to placing rotary target segment **14** on backing tube **16**. Heating causes the diameter of the target material to expand slightly (See Fig. 13b). The expanded target segment is slipped over backing tube **16**. Upon cooling, the diameter of target segment **14** shrinks, thereby making a very tight fit with backing tube **16** (See Fig. 13a). Alternatively, backing tube **16**, usually made from stainless steel or titanium, can be cooled. Target segment **14** material is slipped over smaller diameter backing tube **16**. Upon warming, the diameter of backing tube **16** expands, thereby creating a very tight fit with rotary target segment **14**. Joints located between each individual segment **14** may comprise a square cut, a tapered cut, a lock and key cut or any other joint or seam preferably to create a smooth transition between segments **14**. Materials which have expansion and contraction qualities are useful in accordance with this embodiment.

Threaded Segments

As shown in Fig. 14, another embodiment of the present invention utilizes threading to lock rotary target segment **20** onto backing tube **22**. There are a number of ways of using threaded rotary target segment **20** to form rotary target **24**. In one embodiment, the outer diameter of backing tube **22** is threaded along its entirety or most of its length (see Fig. 14). Rotary target segment **20** preferably comprises internal threads along the entirety of inner diameter of cylinder **26**. Rotary target segment **20** is threaded onto the backing tube **22**, much like placing a continuous string of nuts on a threaded bolt.

In a second embodiment, backing tube **22** and rotary target segment **20** are manufactured such that only a portion of both the inner diameter of rotary target segment **20** and the outer diameter of backing tube **22** are threaded in specific coordinated locations. For example, rotary target segment **20** will easily slide along backing tube **22** until a threaded portion of the backing tube **22** is reached. After a couple turns of rotary target segment **20** the threaded portion of rotary target segment **20** reaches the end of the threaded portion on backing tube **22**. Rotary target segment **20** is then slid to the next threaded portion and the process repeated until all of the segmented threads align with the threads on backing tube **22**.

In each of the two embodiments above, rotary target segments **20** have seams or joints **18** between each individual segment **20**.

Lock and Key

In another embodiment, rotary target segment **34** is slid onto backing tube **36** such that at least one groove **38** in backing tube **36** is aligned with at least one key portion of rotary target segment **34**, or visa versa. Lock and key groove **38** secures the rotary target segment material along backing tube **36**. If multiple rotary target segments are utilized, seams or joints located between each individual segment **34** are smooth.

In each of the embodiments described above, the target cylinder may optionally be secured to the backing tube by means known in the art. These include the use of ductile, low vapor pressure metals such as indium, silver, and alloys thereof, or other securing materials known in the art. Alternatively, the spacing between the target segments and the backing tube may optionally be backfilled with an electrically and/or thermally conductive adhesive, preferably from a metal filled epoxy or other suitable adhesive.

Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above are hereby incorporated by reference.